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COLLOID METALS

BY: E. M. Sataneon

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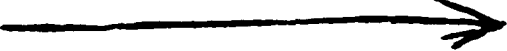
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## 2. Antifriction Properties of the Dispersed Phases

### In Metal Sols\*

The antifriction properties of many metals and alloys are principally the result of the detachment, during the initial contact along the rubbing faces, of highly dispersed particles which form a more or less stable suspension in the lubricating oil /377 to 379/. With the appearance of the suspension there is a sharp reduction in wear and in the coefficient of friction for the contacting metal~~sur~~ surfaces.

On the basis of these facts, M. L. Barabash and E. M. Natanson /380/ suggested the introduction of lubricating oils containing colloidal metal additives between various contacting surfaces, thus sharply reducing the wear on ~~one~~ pairs of surfaces. The authors were guided by the following considerations. The antifriction properties of rubbing surfaces depend to a great extent on the physicochemical state of the surfaces and the layer of oil 

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\*This section is based on materials obtained jointly with M. L. Barabash and G. I. Val'chuk.

which separates these surfaces. In the absence of colloidal metal additives, the lubricating oil usually forms adsorbing solvate layers only on the contacting metal surfaces. In this case the lubricating oil <sup>layer</sup> consists only of two solvate layers and a thin layer of free oil between them /381, 382/.

With the addition of a superfine metallic powder -- the dispersed phase of an appropriate organosol -- the lubricant film separating the rubbing faces changes in structure. Because of the tremendous quantity of colloidal metal particles and because of the formation of a solvate layer of oil on the surface of each particle, almost the entire lubricating layer is in a solvate state.

Thus if colloidal metal is present in the lubricant, instead of ~~only~~ two; numerous solvate oil layers will appear this should effect a favorable reduction in the friction coefficient and in metal wear. <sup>2</sup>

In checking these considerations experimentally, we used conventional pure lubricating oils with additives of dispersed phases of organosols of iron and other metals.

To produce metal organosols (of iron mostly) in lubricating oils by electrolysis, various electrolyzers are used. Diagrams of such electrolyzers are shown in Part Two of this book.

The organosols of iron and other metals in various lubricating oils were obtained by the above method and are referred to as metallo-colloidal lubricants; they have been investigated by many science and research organizations and by industry.

The wear resistance of different contacting surfaces was tested by M. L. Barabash /383, 384/ on a specially designed disk machine which was equipped with devices for measuring the moment of friction, the friction temperature and the speed of rotation along the friction surface. The author followed a procedure of frequently starting the machine; in this way the testing time which is frequently quite long when high-grade lubricants are used, was considerably shortened.

The wear in samples was determined by weight. Here, the running-in period was not taken into account. The following contacting surfaces (friction pairs) were investigated by Barabash: a) bronze OTsS over steel 45, b) globular grey cast iron over steel 45, c) a metal ceramic (with an iron powder base) over steel 45, —————→

d) a metal/ceramic over grey cast iron.

The first two surface pairs are often used as rubbing surfaces, while the last two definitely are of interest because of the prospects of their wide use in the machine-building industry. In addition, samples of contact conductors, which are used in urban electrical transportation systems, were also investigated. The results obtained indicated that the wear of reduced-friction surfaces is directly proportional to the number of testing-machine starts (within a range of from 10 to 50 starts per hour). The author clearly showed the reduced wear obtained by means of lubrication with organosol of iron additives; he also established that there was a regular increase in wear when all of the wear products were removed through a careful cleaning of the disk during the test.

The best results (least wear) were obtained with a metal-ceramic surface rubbing against globular grey cast iron. This pair of surfaces was further investigated, and the dependence of wear on sliding rate, specimen travel and specific pressure was established for 20 starts per hour. The tests also showed that the wear of a metal/ceramic surface over globular cast iron decreases with the addition of an organosol of iron to the lubricant.

The effect produced by the addition of dispersed phases of iron organosol, to lubricating oils on the wear resistance of the worm and worm rim--the basic components of the worm gear at the rear axle of a trolleybus--confirmed the effectiveness of such additives, especially of the dispersed phase of bismuth organosols, which assure reduced wear in these components.



Similar results have been obtained from the investigation of wear resistance in contact conductors widely used in electric transport vehicles (trolleybuses, trolleys, etc.).

Tests carried out along the Kiev trolley bus route # 4 established that the addition of ~~the~~ dispersed-phase ~~in~~ iron organosol to the lubricant, impregnating the lubricant of the metal-ceramic contacts, increases wear resistance by factors of two to three.

The test results obtained at the Institute of Structural Mechanics of the Academy of Science of the Ukr. SSR by M. L. Barabash and G. I. Val'chuk /3850/ are cited below.

Bushing samples made of modified MSCh 38-60 cast iron rubbing over shaft steel 45 (ring) were tested for wear on <sup>45</sup>type MI machine using conventional techniques and an MS20 oil at constant slip ( $v = 0.41$  m/sec); the test was repeated twice: at pressure  $p_1 = 25$  kg/cm<sup>2</sup> and  $p_2 = 100$  kg/cm<sup>2</sup>. In certain cases, higher pressures were used ( $p_3 = 112.5$  kg/cm<sup>2</sup>). The wear was measured (by weight) every 50,000 cycles; the samples were removed from the machine and weighed.

The results of these tests are shown in Fig. 122.\* The effect on wear and friction conditions produced by a lubricant of pure MS20 oil and by the same oil containing additives of colloidal iron, bismuth and also colloidal brass and graphite was studied.

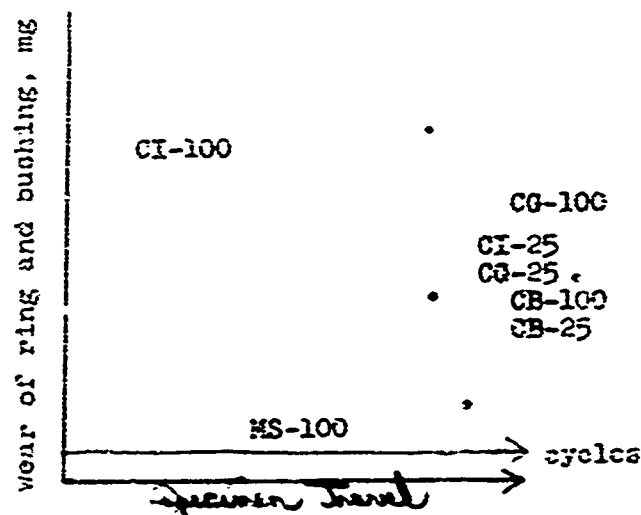


Fig. 122. Wear of normalized steel 45 rubbing against modified (MCI 38-60) cast iron as a function of lubricant pressure, and specimen travel. Lubricant: MS20 oil with additives.

CI) colloidal iron; CG) colloidal graphite; CB) colloidal bismuth;

MS) pure oil, the numbers near notation of lubricant type

indicate pressure in  $\text{kg/cm}^2$ .

\* In Fig. 122, the over-all wear of the ring and bushing is plotted along the axis of ordinates (uniform scale) while specimen <sup>travel</sup> in meters, and number of cycles is plotted along the axis of abscissas (logarithmic scale).

The wear of a steel 45 ring rubbing against a MCI 38-60 bushing

Under a pressure  $p_1 = 25 \text{ kg/cm}^2$ , it was established that the least wear of a steel 45 ring rubbing against MCI 38-60 bushings (Fig. 122) is obtained with a lubricant containing colloidal bismuth. Pure MS20 oil produces somewhat greater wear. Approximately the same wear is obtained with a lubricant containing colloidal iron, but after 100,000 cycle  $N_1$  wear begins to increase and after 150,000 cycles it reaches the wear obtained with a lubricant containing colloidal graphite.

At a pressure  $p_2 = 100 \text{ kg/cm}^2$  the picture is about the same: the least wear was obtained with a lubricant containing a colloidal bismuth additive; the next, in order of least wear, were a pure MS20 oil and an oil containing a graphite additive. At this pressure, the use of colloidal iron results in a properly shaped running-in.

Our attention is drawn to the ring (specimen #370,  $p_2 = 100 \text{ kg/cm}^2$ ) during the first 50,000 cycles, when the wear was 64.4 mg; during the following 50,000 cycles, the wear, although changed, is still considered high (26.0 mg); afterwards it decreases by a factor of ten -- to 2.6 mg. The next 50,000 cycles yield a certain increase-- a wear of 9.4 mg. The wear of the bushings is comparatively small: from 0 to 6.2 mg. Considerably reduced wear was obtained with the same lubricant at a pressure  $p_1 = 25 \text{ kg/cm}^2$  (specimen #371). The wear of the ring varies from 1.2 to 2.4 mg. The wear of the bushing is also very small--on a level with the wear of the bushing at  $p_2 = 100 \text{ kg/cm}^2$ .

The wear of a MCI 38-60 ring rubbing against a MCI 38-60 bushing

At a pressure  $p_1 = 25 \text{ kg/cm}^2$  increased wear may be noted (Fig. 123) when using a lubricant containing colloidal brass (CB), as compared with the wear produced by using pure MS20 oil. There is a sharp change

at a pressure  $p_2 = 100 \text{ kg/cm}^2$ . The least wear is obtained by lubricating with colloidal

iron (CI); this is followed by a lubricant with colloidal graphite and the greatest wear is obtained in lubrication with pure MS20 oil. At a pressure of  $p_3 = 112.5 \text{ kg/cm}^2$ , we have a characteristically

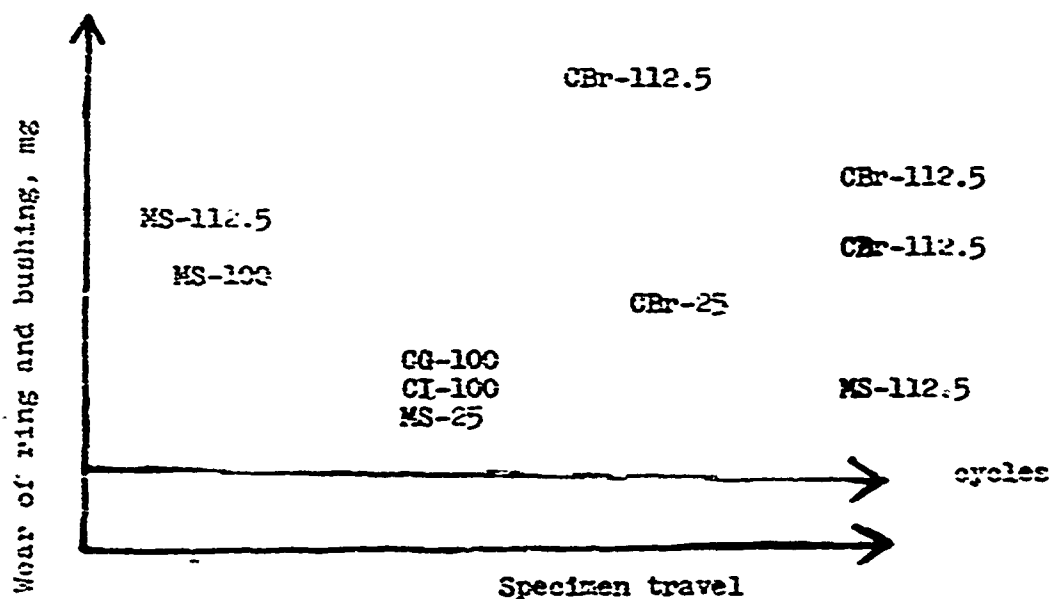


Fig. 123. Dependence of the wear of a modified MCI 38-60 cast iron friction pair on the type of lubricant, pressure and specimen travel. Lubrication by MS20 oil containing different additives. CI) colloidal iron, CG) colloidal graphite, CB) colloidal bismuth, MS) pure oil. The numbers near the notation for the type of lubricant indicate the pressure in  $\text{kg/cm}^2$ .

Translator's note: .3:0.

uniform increase in wear with an increase of pressure. Here it is interesting to note that an increase in pressure after 400,000 cycles (approximately 50 km) produces a sharp increase in wear when using a lubricant containing brass; lubrication with pure KS20 oil, on the other hand, assures a gently sloping curve for the relationship between wear and pressure over the investigated range of specimen travel-- up to 1,200,000 cycles (about 160 km). Good reproducibility of investigation results on an Amstler type machine is characterized by the achievement of approximately identical values of wear for the same distance of specimen travel with step-by-step application of load (curves MS--25 and MS--112.5; CBr--25 and CBr--112.5) with the application of considerable pressure at the beginning of the tests (curve Cbr--112.5). The effect produced by the composition of the solid phase of the metallo-colloidal lubricants on the wear of the given friction pair is clearly disclosed by a comparison of curves CI--100, CG--100 and Cbr--112.5, which differ little in pressure but producing wears of different magnitude.

The wear of steel 45 rubbing against steel 45 and copper

The tests serve the purpose of comparing the effect of the

products produced by the wear of steel 45 and copper with that of the highly dispersed solid-phase particles of brass organosols in MS-0 Oil (Fig. 124).



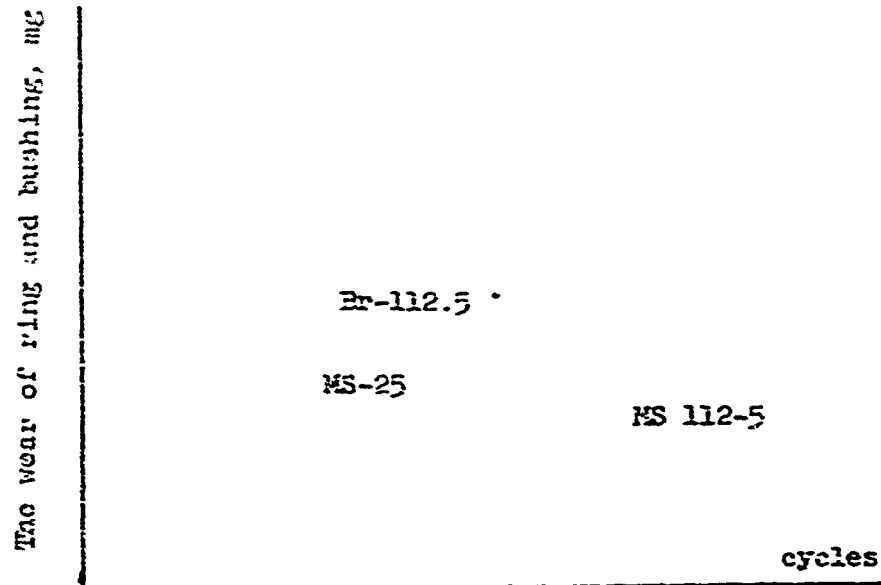


Fig. 124. The wear of steel 45 rubbing against steel 45 and copper. Lubrication by MS20 oil with and without a colloidal brass (CBr) additive. The numbers near the notation of the type of lubricant indicate the pressure in  $\text{kg/cm}^2$ .

A comparison of absolute wear values (for the investigated friction pairs) with data from previous wear-resistance studies of steel 45 rubbing against MCI 38-60 (see Figs. 122 and 123) leads to the conclusion that pressure <sup>is</sup> the deciding factor when a high-grade lubricant is used (in our case it was MS20 aviation oil).

Wear as a function of pressure is described well by a formula of the form

$$\underline{U} = \underline{a} \log \underline{p} + \underline{b},$$

where  $\underline{U}$  is wear in mg,  $\underline{p}$  is pressure in  $\text{kg/cm}^2$  applied to the rubbing surfaces, and  $\underline{a}$  and  $\underline{b}$  are constants found from experience. The method for determining  $\underline{a}$  and  $\underline{b}$  is given in /383/; for the friction pair, a metal ceramic and globular grey cast iron, with a lubricant containing colloidal iron, it was found that  $\underline{a} = 17.258$  and  $\underline{b} = 2.726$ . Hence for the metal ceramic — globular grey cast iron friction surface pair we have

$$\underline{U} = 17.258 \log p - 2.726 \approx 17.3 \log p - 2.8 \text{ mg.}$$

The two constants may be regarded as an indication of the role of two structural factors which participate successively in the development of the processes producing the wear of the friction pair.

The experimental material necessary to disclose the physical meaning of these structural factors and to find the quantitative relationship to determine these factors is not yet available to the authors. Therefore, at this stage we must limit ourselves to a qualitative confirmation of the validity of the relationship given in the last column of Table 54.

TABLE 54. Friction Test Results for Sliding of Certain Metals in the Presence of Colloidal-Metal Lubricants.

Rubbing surfaces	Pressure for sliding friction, kg/cm <sup>2</sup>	Wear of ring and bushing		Type of lubricant	Specimen travel $\times 10^3$ cycles	Wear, mg
		mg	mg per 5 km of travel			
Steel 45 over steel 45	112.5	51 - 85	20	GBr	100 - 600	-
Steel 45 over MCI I over MCI	100	70 - 116	25	CI	50 - 200	32
	100	37 - 59	18	CG	50 - 200	-
	112.5	151 - 166	-	GBr	100 - 600	-
	112.5	8 - 28	-	MS	100 - 600	-
	100	4 - 12	8*	MS	100 - 200	2
Steel 45 over MCI I over MCI	100	3 - 10	7*	CG	100 - 200	-
	100	3 - 8.5	6*	CI	100 - 200	32
	100	3 - 6	5*	GB	50 - 200	-
	85	18 - 23	20*	CG	50 - 200	-
	25	6 - 25	16*	CI	50 - 200	21
	25	2 - 5	4*	GB	50 - 200	-
	100	4 - 8	6*	MS	50 - 200	-

\* Average values.

Evidently wear is affected by the surface shape and structure of colloidal-metal particles introduced into the lubricant; it is also influenced by the adsorptive capacity of these surfaces.

In investigations on Amsler type machines, the friction coefficient of the pair of surfaces under study and the specific work of friction, i.e., the work due to friction, referred to the unit of weight lost as a result of wear from sliding friction.

Figure 12<sup>5</sup> shows a curve of the variation in the friction coefficient as a function of the number of cycles on the same machine during tests.

of the steel 45 (normalized) friction surface sliding over cast iron MCI 38-60.

As may be seen from the data of Fig. 125, at a pressure  $p = 25 \text{ kg/cm}^2$ , the smallest friction coefficient is obtained by using a lubricant containing colloidal iron. The almost horizontal curve, for 200,000 cycles, is typical in this case. At the above pressure a colloidal-bismuth additive yields a higher coefficient than that obtained with oil to which colloidal iron is added.

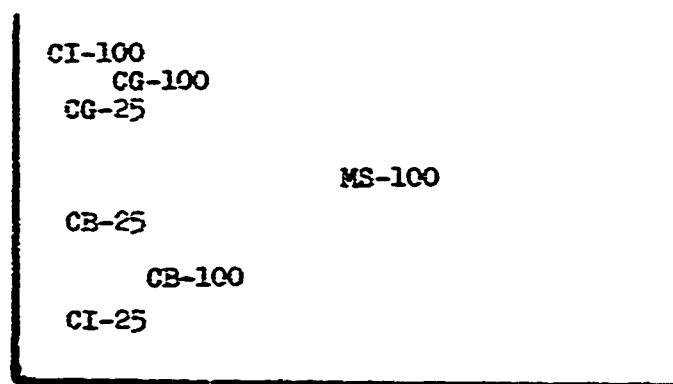


Fig. 125. Dependence of the friction coefficient of steel 45 sliding over MCI 38-60 on type of lubricant, pressure and specimen travel. Lubrication by MS20 oil containing additives. CI) colloidal iron, CG) colloidal graphite, CB) colloidal bismuth, MS) pure oil. The number near the notation of the type of lubricant indicate the pressure in

The picture changes as the pressure increases from 25 to 100 kg/cm<sup>2</sup>.

The smallest friction coefficient (smaller than  $p_1 = 25$  kg/cm<sup>2</sup>) is obtained by using a colloidal-bismuth additive. Colloidal iron and colloidal graphite additives yield approximately the same friction coefficients; these coefficients are somewhat larger than those obtained with pure MS20 oil. It is interesting to note that the colloidal-graphite additive yields the largest friction coefficient; here the coefficient is larger than that obtained with pure MS20 oil, even when the pressure  $p_2 = 100$  kg/cm<sup>2</sup>.

A reduction in the friction coefficient is observed when the pressure is increased from 25 to 100 kg/cm<sup>2</sup> and when the lubricant contains colloidal bismuth.

The tests to determine the friction coefficient of other investigated pairs of friction surfaces, <sup>friction</sup> results which are shown in Fig. 126.

As was to be expected, the largest coefficient was obtained by rubbing steel 45 over steel 45. In this case, colloidal brass was added to MS20 oil and the pressure was raised to 112.5 kg/cm<sup>2</sup>. A

gradual increase in the friction coefficient is noticeable as the specimen travel distance increases.

A considerably lower friction coefficient is obtained by rubbing MCI 38--60 over MCI 38--60. In this case, the addition of colloidal brass, as opposed to lubrication with pure MS 20 oil,

serves to reduce the friction coefficient substantially. Thus within this range of specimen travel (number of cycles), the friction coefficient obtained by lubrication with colloidal brass at a pressure of  $112.5 \text{ kg/cm}^2$  is lower than the one obtained by lubrication with pure MS20 oil at a pressure of  $25 \text{ kg/cm}^2$ .

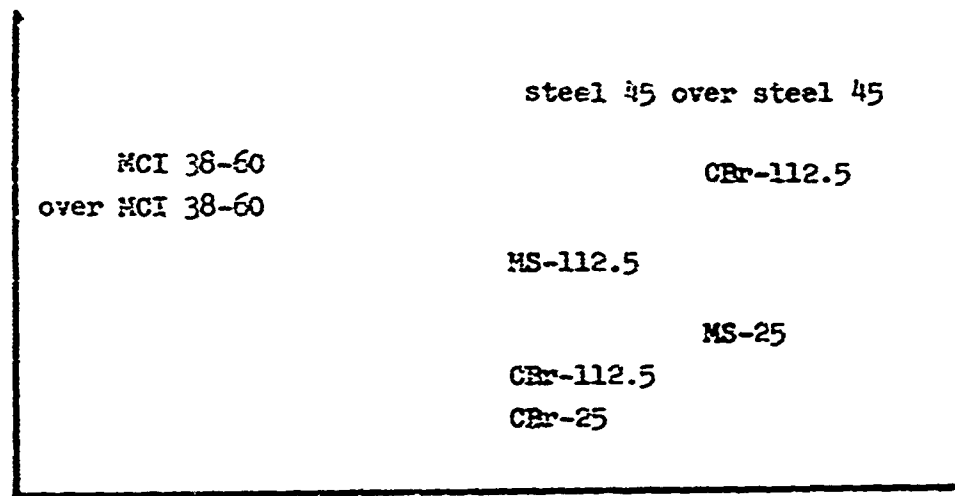


Fig. 126. Dependence of friction coefficient of steel 45 over steel 45 and MCI 38-60 over MCI 38-60 on type of lubricant, pressure and specimen travel. Lubrication with MS20 oil, with colloidal brass (CBR) added. The numbers near the notation of the lubricant type indicate the pressure in  $\text{kg/cm}^2$ .

The curves of Fig. 127 illustrate how the specific work of



friction in the surfaces under study varies as a function of lubrication with pure MS20 oil or with the same oil containing a colloidal-metal additive.

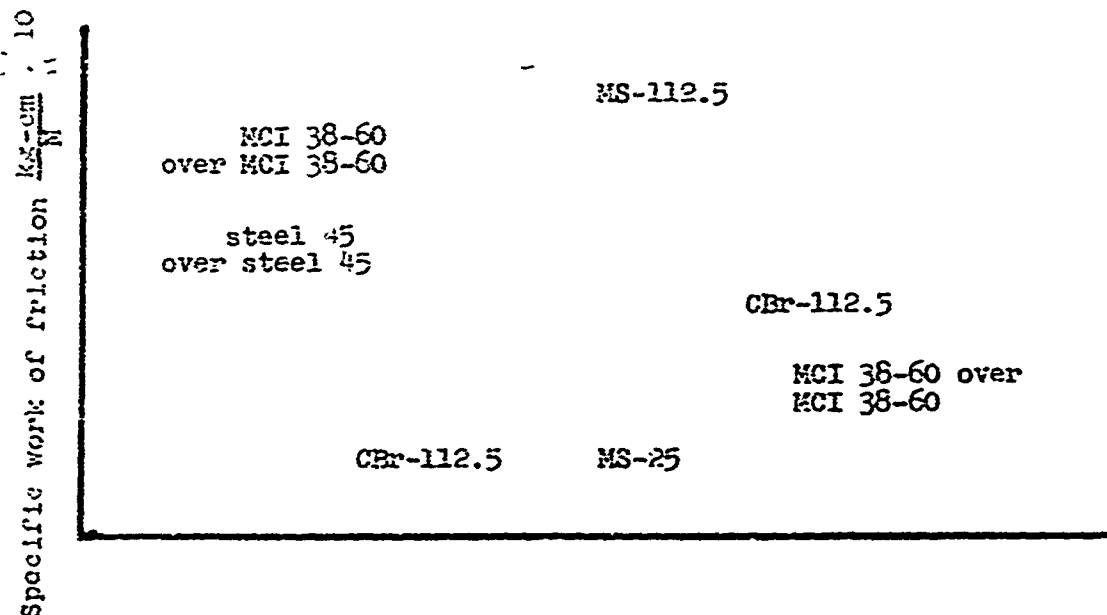


Fig. 127. Dependence of the specific work of friction of steel 45 over steel 45 and MSCh 38-60 over MCI 38-60 on the type of lubricant, pressure and specimen travel. Lubrication with MS20 oil, with a colloidal-brass (CBr) additive. The number near the notation of lubricant type indicates the pressure in  $\text{kg/cm}^2$ .

When MCI 38-60 is rubbed against MSCh 38-60, lubrication with a colloidal-metal additive, as compared to pure MS20 oil lubrication, reduces the specific work of friction over the entire range of pressure from 25 to 112.5  $\text{kg/cm}^2$ .

On the basis of these results, the following facts have been established by Barabash and Val'chuk.

1. Within specific ranges of pressure and specimen travel, wear, specific work of friction and the coefficient of friction are reduced by the addition <sup>to</sup> of the lubricant (MS20 oil) of various metal dispersoids of the colloidal order.

2. The investigation of the steel 45 and MCI 38-60 friction pair showed, at a pressure of  $25 \text{ kg/cm}^2$ , that the least wear resulted from lubrication with MS20 oil to which colloidal bismuth (CB) had been added; this was followed by pure MS20 oil, MS20 oil with an additive of colloidal iron (CI) and colloidal graphite (CG). An increase in pressure to  $100 \text{ kg/cm}^2$  indicated that the addition of colloidal bismuth also produces the smallest amount of wear. Colloidal graphite and iron accelerate the running-in.

3. The investigation of the MSCh 38-60 and MSCh 38-60 friction pair showed, at a pressure of  $100 \text{ kg/cm}^2$ , that the least wear results with a colloidal iron additive; this is followed by colloidal graphite and pure oil. The addition of colloidal brass sharply increases the wear of these surfaces.

. The study of friction in the steel -5 and MSCh 38-60  
friction pair showed<sup>↑</sup> at a pressure of  $25 \text{ kg/cm}^2$ , that the smallest  
coefficient of friction and the least work of friction are obtained  
by using colloidal iron as an additive, while the

largest of these values result from the use of a colloidal-graphite additive. An increase in pressure to  $100 \text{ kg/cm}^2$  yields a lower coefficient of friction when colloidal bismuth is added to the MS20 lubricating oil; a larger coefficient of friction is obtained when colloidal iron and graphite additives are used.

5. In order to reduce wear with pressures ranging from 25 to  $100 \text{ kg/cm}^2$ , it is expedient to use colloidal iron as an additive. At higher pressures (up to  $100 \text{ kg/cm}^2$ ) colloidal bismuth may be used as the additive.

6. With higher pressures ( $80$  to  $100 \text{ kg/cm}^2$ ) colloidal iron additive enhances the running-in.

7. With properly chosen conditions (pressure, type of oil, type of colloidal metal) for the application of colloidal-metal lubricants--organosols of metals--it is possible to obtain a differentiated improvement in the running-in, to reduce wear and heat liberation on the rubbing surfaces of modern machines.

Coating component surfaces subject to friction with thin films of the dispersed phases of organosols of metals is of definite interest.

It is known that tin is the main constituent of many anti-friction alloys. The investigations by H. M. Studzinskiy /386/ established that when specimens of cast iron, coated with layers of various metals (tin, lead, zinc, copper, aluminum and others) are subjected to friction, tin, more so than other metals, considerably improves the antifriction properties of the rubbing surfaces. This property of tin is explained by the fact that it adheres well to the friction surface of the basic metal and exhibits good lubricant adsorption properties. Moreover, tin also has a lubricating effect on metallic surfaces undergoing friction. Studzinskiy arrives at the conclusion that the coating of the friction surfaces with a thin layer of tin (about 5 microns) offers the possibility of considerably widening the field of application of cast iron as an antifriction material.

However, the application of a thin uniform layer on many cast iron component surfaces presents definite difficulties.

We assume that such difficulties can be avoided by coating the rubbing surfaces of metallic parts with a thin layer of the dispersed phase of the organosol of tin in benzene, stabilized with 0.3 to

0.5% of ethylcellulose. Component preheating causes the carboni-  
zation of the ethylcellulose and a durable coat of tin is formed on  
the surface of the principal metal.

the carbon, in quantities of about 5% by weight of tin, usually has a lattice resembling that of graphite and should, in this respect, favorably affect the process of running-in the surfaces under friction.

Films of the dispersed phases of organosols of a number of other metals (iron, lead, bismuth, cadmium, zinc, copper) may be found to be suitable for such purposes, when verified experimentally.

### 3. The Magnetic Properties of the Dispersed Phases of Sols of Metals and Alloys

Superfine powders of ferromagnetic metals and their alloys are used in power machine construction, radio engineering and other branches of industry; these powders are mainly used in the production of permanent magnets and various induction-coil cores used in high-frequency techniques and in radio instruments.

Such cores must possess high magnetic permeability and large ohmic resistance. In this connection, they are frequently made by compacting <sup>a</sup> mixture of metal powders and a dielectric, taken in different proportions. The individual metal particles in such cores possess



high magnetic permeability, and the eddy currents are localized in each of the insulated metallic particles.

Shellac or various high-molecular compounds /387/ usually serve as the dielectric. The dielectric in the core should not be in excess of 9 to 10%. When

this amount is exceeded, the over-all magnetic permeability of the core is sharply reduced.

For the production of magnetodielectric one uses, for the most part, iron powders obtained by the carbonyl method. Because powder particles are nearly spherical in shape, considerably less dielectric is required for the formation of surface insulating films than would be the case for the formation of insulating films on particle surfaces with sharp angles and projections. Attempts to use iron powders obtained by ordinary electrolysis have shown that because of their dendritic shape, it is extremely difficult to have the dielectric cover the entire particle surface thus penetrating every microscopic fissure and pore of the powder particles.

In such cases it becomes necessary to increase the volume content of the dielectric up to 40% and this sharply reduces the magnetic permeability of the cores; it is mainly for this reason that electrolytic iron powders are unfit for the production of cores.

It should be noted that the dispersed phase of iron organosols, a superfine iron powder obtained by electrolysis, is especially valuable in the production of these cores.

Notwithstanding the exceedingly microdendritic structure of such powder particles, their extremely developed inner surface is completely coated with strong adsorbing layers of surface-active substances and a hydrocarbon medium, the instant these are formed on the cathode in the two-layer electrolytic bath. When such dispersed phases of iron organosols are used as superfine powders in the production of cores, the above adsorbing layers may play the role of extremely fine, but strong, films which uniformly cover the entire inner and outer particle surfaces.

1  
2 Cores made of dispersed phases of iron organosols will contain a minimum of dielectric and should possess very high magnetic permeability and considerable ohmic resistance.

Superfine iron powders containing 0.5 to 3.8% Ni were suggested for use as ferromagnetics. These powders are made by thermal decomposition of iron carbonyl which in the form of admixtures contains an adequate quantity of nickel carbonyl in the free space of the heated vessel /388/.

In a number of countries, especially in the USA and England, pure iron has recently been used in the production of magnetic-dielectrics;

however, some very effective alloys have also been used for this purpose /189/.

Permalloy--an iron-nickel alloy (78% Ni, 21.5% Fe) is one such ferromagnetic. The use of a permalloy containing molybdenum (81% Ni, 17% Fe and 2% Mo) is particularly widespread in the USA.

The latter possesses considerably greater magnetic permeability and larger ohmic resistance than pure permalloy.

However, the mechanical crushing of such alloys into superfine powders presents great difficulties; therefore, in order to make them brittle, special additives are frequently used.

Of great interest from the viewpoint of overcoming the above difficulties, is the use of the dispersed phases of organosols of alloys (of the permalloy type) in the form of superfine powders obtained by electrolysis. The expediency of using such superfine powders in the production of cores becomes perfectly evident if we take into account that the magnetic permeability of the cores increases sharply with an increase in the dispersion of the ferromagnetic powder.

In recent times investigators have paid special attention to the property of ferromagnetics to rotate the microwave plane of polarization, since many actual problems of modern engineering can be solved because of this effect. To the present time the above effect was investigated mainly <sup>in</sup> ~~by~~ magneto-dielectrics in which the size of the distributed metal particles was in excess of tens of

microns. In such magneto-dielectrics particle aggregate<sup>A</sup> usually form  
and these frequently come into contact with

each other; this results in large losses to eddy currents. The drawbacks noted above need not take place if dielectrics containing the dispersed phases of metal organosols are used; these organosols are stabilized by surface-active substances. Colloidal particles in such dielectrics may be present as simple domains. Their size corresponds to the region of spontaneous magnetization. In size, the colloidal particles are equal to the depth to which the high-frequency field penetrates the metal.

Proceeding from these considerations, I. A. Deryugin /390/ investigated for the first time the rotation of the plane of polarization of microwaves by magneto-dielectrics prepared on the basis of dispersed phases of organosols of metals obtained by an electrolytic method which we have developed.

Deryugin's calculations of the complex magnetic permeability of artificial ferrodielectrics for metal particle sizes of the order of several hundred angstroms have shown that a major part, over a wide range of frequencies, is a weak function of frequency and retains a value above unity up to millimeter waves. The imaginary component has a maximum whose position is determined by particle sizes and <sup>wavelength</sup> <sub>$\lambda$</sub>



On this basis Deryugin concedes the possibility of dispersing the structure in artificial ferrodielectrics. His investigations of the rotation angle for the polarization plane as a function of magnetic field strength for waves of 69, 16, and 32 mm and as a function of particle dispersion have disclosed considerable rotation of the polarization plane; this rotation is produced by artificial ferro-dielectrics when no external magnetic field is present. The angle of rotation.

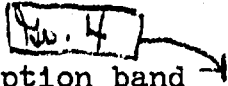
is a function <sup>of the</sup> organosol particle dispersion (Fig. 128). For iron particles several hundred angstroms in size, the spontaneous rotation of the plane of polarization for an 8 mm wavelength reaches  $60^\circ$  per 1 g of ferromagnetic mass.

Fig. 128. The angle of rotation of the plane of polarization as a function of the particle dispersion of the ferromagnetic material.

The rotation of the plane of polarization is a weak function of the external magnetic field. The latter indicates that the internal fields which bring about spontaneous rotation carry the effect almost up to the point of saturation.

No spontaneous rotation is observed when the size of the iron particles is of the order of tens of microns.

Deryugin also established that the rotation of the plane of polarization is directly proportional to the concentration of the ferromagnetic mass in the ferrodielectric and depends on the frequency of electromagnetic radiation.

As a result of thorough investigations, Deryugin developed a new principle of obtaining weakly-reflecting load elements which are easily controlled with respect to frequency; this principle is based on the utilization of resonance absorption in the highly dispersed particles of ferromagnetic metals and alloys. The half-width of the absorption band   $H$  is large because of the losses of the demagnetizing and other factors, and also because of the <sup>structural</sup> dispersion. This effect is strongly dependent on the dispersion of the organosol.

Deryugin also proposed a method of preparing nonreflecting elements in the form of an artificial magneto-dielectric made of highly dispersed phases of ferromagnetic metals and alloys disseminated in polystyrene, plexiglas<sup>y</sup>, rubber and other dielectric materials, and he has established that under certain conditions the half-width of the absorption curve may be anomalously large.

It should be noted that the magneto-dielectrics prepared on the

basis of dispersed phases of organosols of ferromagnetic materials may also be used for power control devices.

An magneto-dielectric alloy consisting of iron, silicon,

and aluminum, the so-called "sandust", has recently come into widespread use in Japan. This alloy possesses high magnetic permeability and large ohmic resistance. It is very brittle and mechanically <sup>it</sup> is easily crushed.

Permanent magnets, it is known, are made of highly coercive alloys. Magnetic alloys possessing a high coercive force usually consist of 12.33% Ni, 5 to 14% Al, 5 to 20% Co, 0.1% Ti, 0.5% Cu.

Superfine powders of metals and their alloys are very valuable materials in the production of permanent magnets, since the production of permanent magnets by casting presents great difficulties which are due mainly <sup>to</sup> the high viscosity of the molten metal and the necessity of subsequently grinding

parts of the magnet until the required sizes are obtained. Therefore in the mass production of permanent magnets, especially of smaller sizes, suitable powders have been used for a long time. With respect to magnetic properties, such magnets cannot be distinguished from the cast variety.

In West Germany permanent magnets are mass produced with alloys of alinium 90 (66% Fe, 22% Ni, 12% Al) and with alinium 120 alloys (58% Fe, 28% Ni, 14% Al).

In addition to alinium, the USA and England produce an alnico alloy which contains 9 to 12% Co, and iron, aluminum and nickel.

The production of permanent magnets from superfine iron powders with particle sizes from 0.01 to 0.1 micron was particularly successful; a mixture of superfine powders of iron (70%) with cobalt (30%) was also used /39/. An alloy of such a superfine iron powder has a coercive force of about 1,000 oersteds.

Powders of an intermetallic compound of bismuth and manganese are recommended as the material for producing efficient permanent magnets. This fusion results from the sintering of the powders of bismuth and manganese, taken in a ratio of 83.35:16.65 by weight,

in an inert gas at a temperature of  $700^{\circ}$  in a rotating furnace /392/.

We have developed the technology of obtaining magnetic components made by compacting superfine powders based on iron and the properties of these components have been studied.

Iron powders with colloidal dispersion (particle sizes from 0.01 to 0.1 microns), obtained by the reduction of iron formate at a low temperature in hydrogen, are widely used for the production of "gek alloy" permanent magnets which have a density of 4 to 5 g/cm<sup>3</sup> /393/. The coercive force of such magnets may be of the order of 1,000 oersteds. No spurious currents appear when these magnets are used in various devices. Components of superfine powders have magnetic properties which are not inferior to those of magnets made of costly special magnetic steel; they are less dense by factors of two to three, require less basic costly materials and their production is considerably simpler. These components are needed particularly for work with high-frequency currents and for precise control of magnetic permeability /349/. However, in obtaining highly dispersed iron powders and in working with them, we encounter serious difficulties which are mainly the result of the pyrophoric properties of these powders /395/.



It is also important to take into consideration that the magnetic properties of superfine powders depend to a considerable extent on the shape

and structure of their particles and these properties are especially high when the crystals are anisotropic.

It is known that magnetic crystal anisotropy is fairly high when particles are elongated in shape, or when strong anisotropic stresses are present /396/. Ordinarily such particles have considerable effective internal energy.

To make highly dispersed metallic powders suitable for molding permanent magnets, their particles must possess high anisotropy energy, have a high moment of magnetic saturation and a high Curie temperature.

A number of authors have attempted to increase the coercive force of magnetic components made of superfine iron powders, but they did not meet with success, since the heat treatments which they used to prepare such powders produced for the most part, in spherical particles shape. In this respect, our special attention should be turned to the dispersed phase of iron organosol obtained by electrolysis. As we have already pointed out, this is an iron powder dispersoid of the colloidal order, whose particles have a sharply defined microdendritic structure.

Superfine iron and other ferromagnetic metal powders and alloys, present in various organic media in the form of the corresponding organosols, may also find a wide range of application in the so-called magnetic-powder <sup>process for the</sup> detection of defects.

This process is usually employed in the inspection of various products made of iron and other ferromagnetic materials; here two methods are used:

- 1) the products to be inspected are preliminarily magnetized, after

which they are sprinkled with a suspension of ferromagnetic powder and the residual magnetization of the material is utilized to disclose the defects;

2) the products are sprinkled with a suspension of ferromagnetic powder at the instant at which they are under the action of a magnetic field.

The method used depends on the nature of the material, its magnetic properties, the shape and size of the products. The inspection of magnetically soft steel components takes place at the instant the magnetic field is applied. In most cases, however, we use the method of residual product magnetization, obtained by passing a short-duration electric current through the product.

When the magnetized products contact the ferromagnetic powder suspension, most of the particles are attracted to the defective points if these are on the surface layer of the product and are extremely thin cracks invisible to the naked eye.

The ferromagnetic powder particles, which have thus accumulated on the surface of the product, indicate the location of the defects.

The magnetic powder method of detecting defects is based on the

change in magnitude and direction in the flux of magnetic force

lines passing through

the specimen being tested when obstacles having smaller magnetic permeability are encountered in the path of the magnetic lines of force. These obstacles are, in the main, such defects as cracks, blow holes, <sup>scale</sup> scale, nonmetallic inclusions, blisters, etc.

Lines of force are scattered at these defective points and a sharply expressed magnetic field nonuniformity becomes evident. These circumstances, for the most part, are responsible for the accumulation of ferromagnetic powder particles in the defective areas /397/.

It should be taken into consideration that the defects are particularly evident when they are perpendicular to the direction of the lines of force. It is therefore necessary to select magnetization conditions so as to obtain the most favorable direction for magnetic force lines.

The location of defects depends to a great extent on the dispersion of the ferromagnetic powder, on the stability of its suspension and the nature of the product surface to be inspected. Increasing dispersion in the ferromagnetic powder greatly enhances the powder's penetration into the defective places, thus clearly fixing these points.

The stability of the suspensions must be such as to prevent a spontaneous settling of a solid layer of ferromagnetic particles on the surface of the product when the suspensions come into contact with the product during the inspection of its quality. To avoid

this we must select the optimum concentration



of ferromagnetic powder. When the concentrations are high such a powder settles out on the surface of the product under inspection in the form of a solid layer; with low concentrations the time spent in inspection is prolonged considerably.

From the viewpoint of dispersion and stability it is important to take into consideration that the organosols of iron and other ferromagnetic materials present in different hydrocarbon media are the most suitable <sup>2</sup> systems for using the method of detecting defects with powders.

The nature and condition of the product surfaces undergoing inspection are no less important. The surface must be lyophilic with respect to the dispersed medium; the amount of stabilizing substances--high molecular compounds usually present in the organosols of iron and ferromagnetic alloys--should be at a minimum and would not be an obstacle preventing contact between ferromagnetic particles and the surface of the products undergoing the test.

The surface of the product undergoing inspection should first be made hydrophobic by washing it repeatedly with anhydrous acetone and aviation gasoline. Treating the surface in this manner results in the almost complete

removal of the adsorbing layer of water which is usually present on the surface of any metal in contact with the air which always contains water vapors. In this case the acetone molecules displace the molecules of the adsorbed water from the surface of the product being inspected and from all macro- and micro-fissures present at the surface of the product. As a result the surface becomes intensely hydrophobic and this enhances its wetting by the dispersed medium of the organosol;

it also enhances the deep penetration of the colloidal ferromagnetic particles into the macro- and micro-fissures, and also their accumulation in such places.

Figure 129 shows a crankshaft pin before and after its inspection by the powder method of detecting defects.\*

a

b

Fig. 129. Crankshaft pin before inspection (a) and after (b).

In using the described method it is important to know that on surfaces containing no defects which could serve to reject the component, occasionally a thin ferromagnetic powder settles so as to

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\* This photo is taken from the book by A. V. Shigadlo, T. D. Kubyshkina, and O. N. <sup>Podvoyska,</sup> ~~Provoyskiy~~ "Inspection of aircraft components by the magnetic powder method." Oborongiz, 1951, p. 75.

suggest that such defects are really present. A similar phenomenon occurs when the component surface is not homogeneous; for example, when there is carbide striation in the structure of the metal. In such doubtful cases,

the obtained results must be verified by appropriate microanalysis.

.. The Use of Highly Dispersed Metal Powders  
in the Machine Building Industry

At the present time metal powders are widely used in the machine building industry for the production of gear wheels, templates, piston rings, porous bearings, ammunition rotating bands, friction disks, electrical contact materials, heat-and oxidation-resistant components for jet engines, various types of hard alloys and a large quantity of special-purpose components.

Components produced by powder metallurgy methods are almost completely free of the defects which are observed in components

produced by casting and which depend principally on the crystallization process, i.e., the transition of the metal from the liquid to the solid state.

It is known that powder metallurgy methods are very advantageous from the viewpoint of simplifying component processing economizing on raw material.

The wear resistance of metal-ceramic components is high; this is especially characteristic for metal-ceramic products first impregnated with oil.

An important advantage of porous products (e.g., porous iron bearings impregnated with oil) is their property of "self-lubrication". In this case, the highly developed inner surface of the porous bearings is covered with a layer of lubricating oil. Therefore no special external oil supply is required for such bearings and this is extremely important for friction surfaces which are not easily accessible.

In the production of bearings, 2 to 3% of graphite is frequently added to the iron powder. The graphite forms a suspension in the lubricating oil which fills the pores of the bearings; the

suspension sharply; reduces the coefficient of friction and improves wear resistance in the bearings. The porosity of such bearings is 15 to 30%.

In addition to graphite, 0.5 to 5% Pb or 10 to 20% <sup>Cu</sup> was added to the iron powder in the production of porous bearings. However, this was impractical since the lead and copper did little to improve the quality of the bearings /398/.

At the present time porous bearings are impregnated with 3 to 7% molten sulfur (by weight of bearing). Such bearings have a higher quality than ordinary bearings, they are able to operate under a load of up to 25 kg/cm<sup>2</sup> and at speeds of up to 78 to 80 m/sec; they will tolerate a considerable increase in temperature and do not require additional lubrication. /399/.

The impregnation of porous bearings with synthetic resins also brought positive results.

Porous bearings, instead of cast bronze, brass and plastic bearings, may be successfully used in various branches of the machine building industry.

The basic raw material for the mass production of many forms of metal-ceramic products are iron powders obtained by various methods.

Iron powders are now mostly obtained by reducing crushed ore.



mill scale with generator gas or stored natural gases /400, 401/.

The reduction is usually accomplished in rotating furnaces. The process proceeds quite rapidly and completely, especially as the gas passes through the

material being reduced and swirling takes place. Under such conditions, ore or scale reduction begins at the instant the ore or scale are suspended in the form of dust. The latter is attained either by a rapid rotation of the furnace, or by automatic vibration.

Reduction of crushed ore or scale in shaft-type furnaces is very promising.

Iron powder production by the reduction of mill scale with natural gas has been investigated in detail and developed on an industrial scale by I. N. Frantsevich, I. D. Radomysel'skiy and others at the Institute of Metal-ceramics and Special Alloys of the Academy of Sciences Ukr. SSR /402/.

Iron sponge is obtained by reduction, crushed in a hammer mill, and the powder is sieved through corresponding screens. Such powders usually have a content (in %) which is approximately as follows: not less than 98.5% Fe (of the total), not more than 0.1% C, not more than 0.4% Mn, not more than 0.1% Si, not more than 0.01% S, not more than 0.4% of the residue in soluble in hydrochloric acid, including Si.

In order to obtain 1 ton of iron powder we need 1.43 tons of scale and 2,000 m<sup>3</sup> of natural gas.

Most of these powder particles have sizes from 0.15 to 0.25 mm.

This method is characterized by a comparatively high yield from the basic equipment and by the ease of the process. Iron powders

obtained by this method almost ~~will~~<sup>need</sup> cold harden and ~~used~~<sup>need</sup> no  
tempering before compacting; this is in contrast to the powders  
produced

by swirling electrolysis and other methods.

With industrial needs in mind, I. N. Frantsevich, I. D. Radomysel'skiy, I. M. Fedorovich and others /403/ developed the following types of powders: APZnM--for the production of iron-graphite products APZnV--for reduction in the production of pigments, APZnF--for oxy-flux cutting, APZnD--for magnetic detection of defects. These powders are easy to compact. High brick strength over a wide range of porosity makes possible automatic compacting under mass production conditions. Powders have been found to be perfectly suitable for oxy-flux cutting and magnetic-powder detection of defects.

Of the other methods, thermal decomposition of iron pentacarbonyl  $\text{Fe}(\text{CO})_5$  is important. This method yields superfine and very pure iron powders which are mainly used for the production of magnetic, vacuum and other types of porous products. However, due to their high cost, powders find limited application. Iron powders are frequently made by electrolysis in which the iron (in sulfate or other baths) is deposited on the cathode in the form of a coarsely dispersed powder or in brittle lumps which are subsequently crushed mechanically and screened through sieves to obtain sufficiently dispersed powders.

Iron powders are also produced by wide-spread methods involving the atomization of molten iron/

or often cast iron and by a mechanical grinding operation in an eddy mill. In the latter case, it is necessary to obtain from the iron a calibrated wire, the clippings of which are subjected to crushing.

It is important to take into consideration that the technological properties of iron powders are largely determined by the size of their particles. In most cases decreased particle sizes and increased specific surface of iron powders considerably improve mechanical properties in products made from such powders.

In oxy-flux cutting when powders are used as the basic component of the powder-like flux powder efficiency increases as dispersion increases. This is also true when powders are used as reducing agents in processes transforming vat dyes into vat sols (indigo into indigosol) or when they are used in magnetic-powder detection of defects, etc.

Especially promising is the use of iron powder mixtures carefully dispersed and containing 80 to 85% ordinary powder obtained by one of the above methods, and 20 to 15% of superfine iron powder obtained by the carbonyl method or by electrolysis.

Superfine powders of other metals are used mainly as contact and  
braking materials and also for the production of hard, high-melting,  
heat-resistant and scale-resistant materials required for the production  
of jet aircraft components



and metal cutting tools.

Electrical-contact materials must have low contact resistance-- high electrical conductivity, high thermal conductivity, high resistance to electrical erosion and high wear resistance. They must be corrosion resistant, easily run-in and little tendency to stick.

Among contact materials there are metal-carbon, pseudo-alloy, metallic, carbide and metal-oxides. In the production of sliding contacts--electrical motor brushes, we use, for the most part, a mixture of graphite powder (up to 75%) and copper (up to 25%). In the USA, tin, zinc and lead are added to such compounds.

The German literature discusses the production of electrical brushes from a mixture of superfine silver and graphite powders with an admixture of copper.

The technology of electrical brush production is simple. The mixture of powders containing up to 9% of graphite is compacted without the addition of binding substances. Pitch or other resins are added to the mixture being compacted when the graphite content is higher. After pressing, the blanks are sintered. The coking of the resin or pitch then follow and the stable three-dimensional lattice *is formed, holding the particles of the metallic powder*

Medium output contacts are made from a mixture of fine silver and cadmium oxide powders /204/. Such contacts have small tendency to stick. Moreover, cadmium oxide dissociates at comparatively low temperatures and this protects the silver from the effect of extraneous gases and causes the arc-suppressing action of the contacts. The electrical conductivity of such contacts reaches 95% of the electrical conductivity of pure copper.

High output contacts (above 1,000 v and 1,000 a) are made of fine pseudo-alloy powders (W -- Cu, Ag -- Ni, W -- Ag, Mo -- Ag), and also from high-melting metals (tungsten, molybdenum) and hard alloys. These contacts are unique because of their high melting and vaporizing points and because of their considerable strength.

The very finely dispersed mixtures for the production of W -- Ag contacts are obtained by the reduction of the previously precipitated tungstate of silver  $Ag_2WO_4$ .

The construction industries of electrical machinery in the Federal Republic of Germany, USA, France and other capitalist countries make wide use of contacts made of pseudo-alloys.

Contacts with a tungsten and molybdenum base have high electrical

conductivity, strength, resistance to wear, welding and high resistance against electrical erosion.

Fine metal-ceramic hard alloy powders are also used widely in the production of metal-cutting tools.

The basic alloys are WC -- Co, WC -- TiC -- Co and WC -- TiC -- TaC (NbC) -- Co.

In the production of machinery and instrumental hard-alloy components, fine powders of WC -- Co alloy are most often used.

The cobalt content in such systems varies within a fairly wide range. Parts not subject to impact loads contain 6 to 9% Co; those subjected to small impact loads--9 to 12%, those subjected to very high impact loads--15 to 25% Co.

For the production of braking materials, we use a mixture of fine powders of copper (50 to 75%), tin (5 to 10%), lead (6 to 9%), graphite (5 to 8%), iron (6 to 10%) and silicon (about 0.6%).

Braking materials must meet fairly high requirements. The products made from such materials must very effectively and rapidly brake the rotation from a speed of 20,000 rpm to zero in less than 0.1 sec. In this case, the heating of the friction disks reaches a temperature of up to 500 to 600° and this must be taken into consideration when selecting the corresponding powder mixtures.

In conclusion it is necessary to note that the high degree of dispersion of the raw metallic powders in the composition of the mixtures which are used for the production of the enumerated and other metal-ceramic components, favors a greater uniformity in their distribution

in the finished products. Therefore the physical and mechanical properties of the products are considerably improved and the use of the latter at high temperatures is facilitated.

#### 5. Corrosion Resistant Highly-Dispersed Metallic Powders

One of the important tasks of powder metallurgy is to reduce corrosion in a number of metallic powders. In the works by P. A. Rebinder and V. I. Likhtman /405/ it is shown that the treatment of metallic powders with solutions of oleic acid in benzene or in kerosene oil improves their corrosion resistance. The authors have established that the use of such solutions as active lubricants in the processes of sintering and compacting the metallic powders facilitates the plastic deformation of the powder particles, results in closer packing and the growth of the contact surface between them. The sintering of the powders in the presence of such active lubricants considerably improves the physical and chemical properties of the products.

It was established that protecting the particle surfaces of powdered metals (copper) against moisture by making their surfaces hydrophobic through adsorption with surface-active substances assures

the powders a lasting and reliable protection against corrosion. In this case the protective methods should be so selected as to keep the metallic powders from oxidizing in all stages of production.

Obtaining superfine metallic powders, as we have suggested, by electrolysis with a two-layer electrolytic bath is of definite interest.

We have described above the basic principles of this method and the types of electrolyzers for obtaining organosols and superfine metallic powders on a large scale.

The metallic powders thus obtained are vacuum dried after careful removal of the aqueous layer of the electrolyte.

The above method offers the following advantages as compared with ordinary methods of obtaining powders electrolytically.

- 1) the surfaces of the powder particles become hydrophobic at the instant they are formed on the cathode; this considerably reduces the oxidation of the powders;

- 2) the continuous removal of the centers of crystallization from the area of ion discharge in the metal and the adsorption of the insoluble (in water) surface-active substances at the surface of the rotating cathode considerably increase the polarization of the latter, which to a considerable extent enhances the increased dispersion of the deposited metallic powders;



) by varying the velocity of cathode rotation we can, to some degree, influence the dispersion of the metallic powders in the process of their formation.

## 6. Structure-Forming Properties of Dispersed Phases of

### Sols of Metals in Contact with Rubber Cement

A very interesting fact has been developed from the investigation of the stability of the sols of superfine metallic powders (iron, bismuth, and others) in various organic media: the addition of a comparatively small quantity of rubber to such systems increases their stability hundreds of times. As it turned out the colloidal particles of these metals are not completely insensitive to rubber. On their appearance in the rubber cement, they interact with the highly branched macromolecules of rubber and form corresponding adsorbing compounds. This process is probably taking place in two directions.

On the one hand, individual macromolecules of rubber interact simultaneously with different links with several metallic colloidal particles. Such an interaction takes place because individual thread-shaped macromolecules of rubber, in length frequently exceed the average of metallic colloidal particle sizes many times. In this connection some sort of chainlike aggregates of different shape and

length consisting of several such colloidal particles bonded by individual macromolecules of rubber appear in the rubber cement containing metallic colloidal particles.

On the other hand, the second process proceeds simultaneously and no less intensively in the rubber cement containing the colloidal metal particles:

the individual colloidal metal particles interact simultaneously with the links of various macromolecules and bond them together.

As the result of these complex processes, there appears in the rubber cement a structural lattice in which the individual colloidal metal particles act to bind the links of various macromolecules.

Consequently, because of the presence of colloidal metal particles, the rubber cement acquires structural-mechanical properties.

This circumstance is especially clearly seen in studies on changes in deformation as functions of shear stress of rubber dissolved in xylene, before and after the addition of a superfine powder--the dispersed phase of the organosol of iron. After the addition of such a powder, a sharply defined ultimate shear stress appears in the system. Simultaneously there occurs a considerable increase in the viscosity of the rubber cement, and depending on the pressure, the viscosity becomes anomalous.

We must take into account that such a sharp change in the properties of rubber cement take place even in the presence of very small additions of a superfine metallic powder (0.05 to 0.1% Fe).

The stated facts point to the expediency of a practical application of superfine powders--dispersed phases of organosols or metals in the form of additives to industrial rubber cement. Such additives, which bring about conditions

for the appearance of structure in the rubber cement, must play the role of very effective rubber fillers. They improve the technological properties of the cement and the quality of the industrial rubber products obtained from the cement. In this case, the high colloidal metal particle activity with respect to rubber can be explained to a large extent by the extreme hydrophobization of their surface; this takes place at the instant the particles are electrolytically formed and as a result of the adsorption of the fatty acids on their surface.

The chemical nature of the metal, however, also plays an important role. In this respect, the dispersed phases of organosols of zinc, iron and bismuth are the most effective.

When the dispersed phase of some metal serves as the additive to rubber cement, it is necessary to ascertain the optimum quantitative relationship between the colloidal metal and rubber in the cement. This relationship determines the strength of the formed structural lattice. From the standpoint of technology, not every structural lattice may be suitable. It is important to take into account that as the ratio of colloidal metal to rubber increases progressively,

the strength of the formed structural lattice at first increases, and then, after reaching a certain maximum, decreases sharply.

It is also necessary to ascertain the influence of time on the change in the properties of industrial rubber product made of cement containing as additives superfine powders--dispersed phases of organosols of metals. Here, we have in mind mainly the aging processes in such products.

Moreover, the dispersed phases of organosols of certain metals (zinc, iron and others) may be utilized in the production of industrial rubber goods as one of the components of the rubber mixtures. It has long been established that the strength of rubber mixtures increases with an increase in the dispersion of the filler. The strengthening action is exhibited mostly by fillers containing particles of the colloidal order of dispersion. The strengthening depends on the specific surface of the filler and nature of this surface.

For the filler to act effectively, it is necessary that each of its particles be surrounded by rubber molecules and that the inner surface of these particles also be in contact with rubber molecules.

The physical and chemical bases of the mechanism of interaction between the fillers and rubber are discussed in detail in the works of P. A. Rebinder, V. B. Margaritova and others /-06/.



According to their concepts, on ordinarily hydrophilic surfaces of colloidal metal particles which are introduced as components of the rubber mixture, there occurs an oriented adsorption of the "disphilic" molecules of the surface-active substances--fatty acids, albumins and resinous substances which are present <sup>in rubber</sup> in the form of admixtures or a special additive to the rubber mix. In this case the adsorption is referred to as oriented

because the adsorbed molecules are oriented at the boundary between the metal and rubber so that their polar group is directed toward the surface of the metal, and their nonpolar group--to the rubber. Such an orientation is frequently accompanied by chemically fixed adsorptive layers. Because of these layers, the surfaces of the colloidal metal particles become very lyophilic to the rubber and this favors the interaction of the particles with individual lines of various rubber macromolecules and the formation of a strong structure.

I In addition to this general scheme, the strength of the structure of the "rubber -- superfine metallic powder" system is decidedly <sup>affected</sup> by specific features of the chemical nature of the dispersed phase of the organosol of the metal present in the system. The organosols of iron, zinc, bismuth and others, have been found to be especially active in this respect.

It is obvious that in adding a dispersed phase of organosol of metal to the rubber we should take care to have the colloidal metal particles distributed uniformly in the rubber, and see to it that no particle accumulation -- "lumps" -- should form in the system.

We must also bear in mind that the interaction between rubber  
and the dispersed phase of organosol of metal is also <sup>substantially</sup> ~~subsequently~~  
affected

by other components ordinarily present in the composition of rubber mixtures, and also by the sequence of mixing these components.

To avoid the effect of these factors, it is expedient to prepare the rubber mixtures by maintaining the following sequence: the superfine powder--dispersed phase of organosol or metal--is first treated with an appropriate amount of stearic acid and then distributed uniformly in pure rubber; the system thus obtained is thoroughly mixed with the other components of <sup>the</sup> rubber mixture.

Because of this method of handling, the surfaces of the colloidal metal particles become completely <sup>hydrophobic</sup> ~~hydrophilic~~, and their contact and interaction with individual links of rubber macromolecules take place without any influence from the other components of the mixture. Since the percent by volume of the dispersed phase of metal is small compared to that of the rubber, the latter forms a continuous external phase -- a unique dispersed medium -- in which the colloidal metal particles are almost completely prevented from interacting with other components of the rubber mix.

In conclusion, we consider it necessary to note that the effect of admixtures of superfine metallic powders on the physical and mechani-

nal properties of rubber and industrial rubber products made from  
these powders has, at the present time not been fully investigated.

~~may~~  
In connection with the high adsorptive capacity of metals with  
respect to admixtures of fatty acids, albumin and resinous substances  
ordinarily present in natural crude rubber,

and also with respect to the unsaturated bonds of rubber macro-molecules, there is sufficient reason to assume that small admixtures of a number of metallic superfine powders to rubber may very effectively influence the physical and mechanical properties of industrial rubber products.

The material written in this section of the book points to the necessity of extensive investigations to ascertain the possibility of using superfine powders--dispersed phases of organosols of many metals -- as effective intensifiers of the physical and mechanical properties of industrial rubber products. The timely need of selecting such intensifiers becomes perfectly obvious, if we take into account the very much higher demands made at the present time on the various rubber products by the aircraft and automobile industries.